J. Aquat. Plant Manage. 31: 157-162

Vegetation Zones along Watercourses: Inter-Relationships and Implications for Mechanical Control

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ABSTRACT

The effect of mechanical control on vegetation structure and species composition of watercourses was studied. Samples were taken of each vegetation zone in a number of watercourses in The Netherlands for which the management regime was well-documented. In most cases a series of two to five vegetation zones could be distinguished along watercourses. Mechanical control measures take this zonation into account treating each zone differently. Classification of 1365 zone samples, using Braun-Blanquet methods, produced groups of samples which were related to differences in management practices in several ways. Both the type of machinery used and control frequency affected species

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composition in some zones. Analyses of the combinations of zone types for each watercourse by a second order classification showed relationships between these zones. The role of *Glyceria maxima* dominated zones is discussed.

Key words: gradients, classification, aquatic plants, *Glyceria.*

INTRODUCTION

The practice of vegetation control in watercourses in The Netherlands has changed greatly in recent decades. Herbicides have been used for some time but their use in watercourses is now very restricted, and will be banned completely over the next five years. Vegetation growth in 95% of the watercourses in the Netherlands is controlled mechanically. The scale of the maintenance problem has increased because many water drainage systems have been improved to make agriculture more profitable. With the planning of these drainage systems it was assumed that aquatic plants could be controlled effectively by repetitive control measures. However, when aquatic plant growth increased more than was expected, either frequency of control was increased, or more powerful machines were used. As a result there was a shift in the flora to opportunist species which create even more management problems.

One of the difficulties in research on vegetation in watercourses is describing the plant communities. There is a strong gradient on the slopes of the watercourses with species that have a range of environmental demands. The Braun-Blanquet approach of vegetation research (Westhoff and Van der Maarel 1973) is commonly used to describe vegetation types that can be related to environmental factors, but this method needs homogeneous sample plots. Sampling the whole gradient gives no practical description of the vegetation because of the heterogeneity. Mechanical control techniques in watercourses affect vegetation structure and species composition both above and below the water. An adequate description of the bank vegetation as well as the aquatic vegetation is essential for understanding the impact of the control techniques on the whole gradient.

In this study the gradient is split into zones of vegetation that are recognizable through their structure or species dominance. Within each zone, the vegetation is considered to be more or less homogeneous. The zones are analyzed separately and in combination to determine the relationships between mechanical control techniques and the vegetation in watercourses. This paper presents the method of splitting the gradient into zones and gives some results relating to differences in management practices.

METHODS

The watercourses sampled were selected on the basis of previous management practice, soil type and landscape type. They all had a drainage function, but water flow in most of them was very slow (standing or less than 5 cm/sec). Management practice was well-documented and had been constant for at least five years. Extremes in water quality were avoided. The vegetation in the watercourses was divided into zones as shown in Figure 1, but no watercourse was found in which all the zones were present. Between two and five zones could be distinguished consistently in most watercourses. When no separate bank top zone could be distinguished, that part of the profile was considered as a part of the dry bank slope zone. Likewise, the permanently wet ground zone could be part of the emergent plant species zone and the floating-leaved plant species zone could be part of the submerged plant species zone. The width of the zones varied from 0.3 to 5 m. The length of the sampled area was determined by the minimum area to cover all the variance within each zone sample but not including gradients. This length varied from 10 to 50 m. When two banks on opposite sides of the same watercourse were sampled, they were treated separately.

All macrophyte species for each of the zones were recorded. An estimation of their presence was made using the combined cover-abundance scale of Braun-Blanquet, modified by Barkman *et al.* (1964) into a scale with nine ordinal classes. Scales 1-4 concern species with cover less than 5%, the number of individuals per 10 m^2 determines the scale: 1 = 1-2, 2 = 3-20, 3 = 21-100, 4 = more than 100. Scales 5-9 concern species with cover more than 5%: 5 = 5-12%, 6 = 13-25%, 7 = 26-50%, 8 = 51-75%, 9 = 76-100%. All zone sample data were analyzed using TWINSPAN (Hill 1979) to classify the samples into groups. The indicator value of the species was weighted using their cover-abundance in the samples. Classification results were summarized into a synoptic table in which constancy classes and characteristic presence of the species for each group are indicated (Table 1). Constancy classes are: + = species found in 1-5% of the samples in the group, 1 = 6-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, 5 = 81-100%. The characteristic presence of a species is defined as the mean cover-abundance class, considering only the samples in the group in which the species actually was found.

The management techniques were described in terms of machinery and control frequency (number of times per year). These data were compared with the classification groups by calculating their constancy class for each group. Constancy

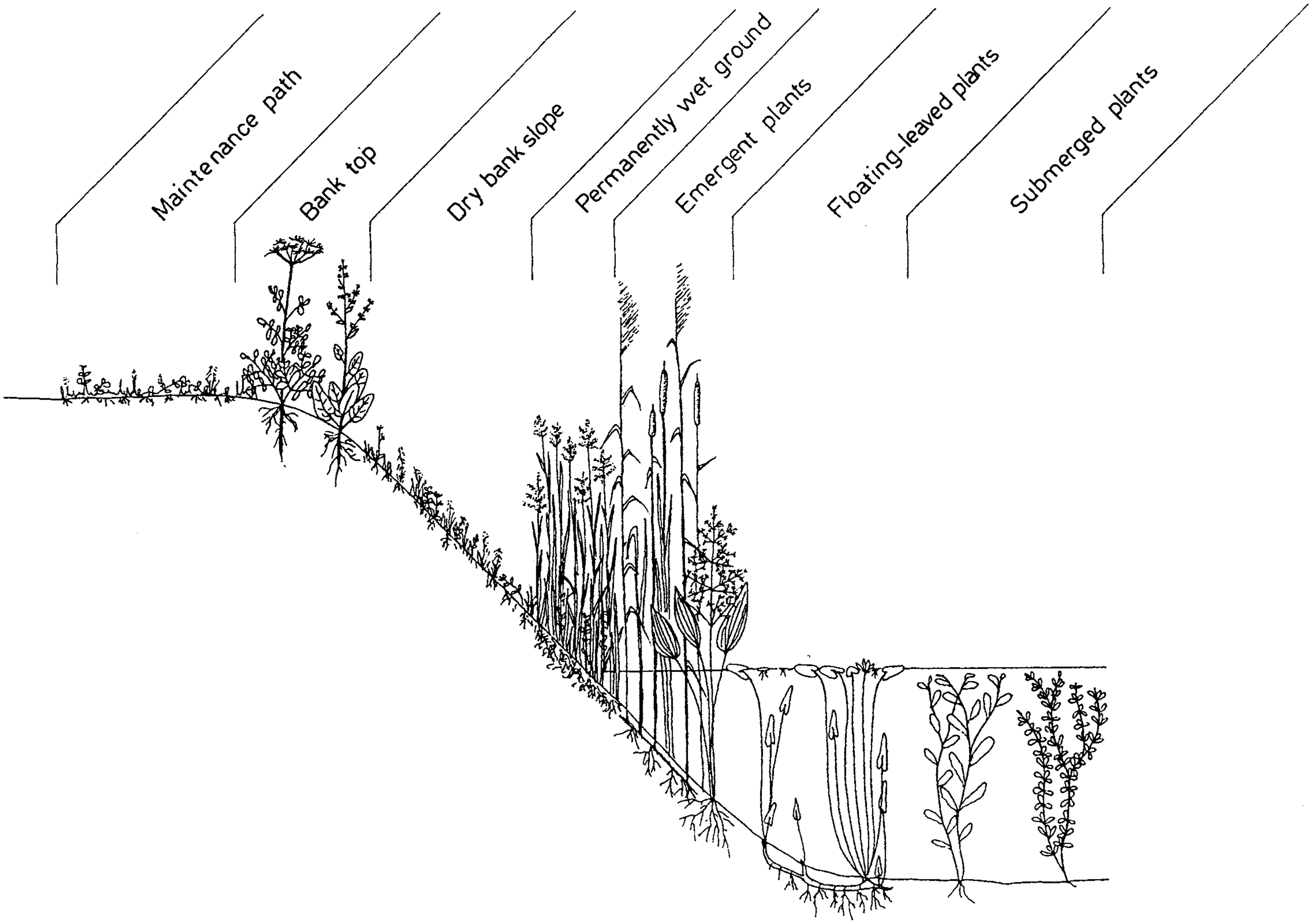

Figure 1. Zonation scheme in watercourses. Only part the zones are found in any particular watercourse.

class is defined in the same way as for species: + = machine applied in 1-5% of the samples in the group, etc.

The results of the classification were used to describe the gradients in the watercourses as a whole. A gradient sample was defined as a combination of the zone samples of a watercourse. For this, the zone samples were encoded as zone types using a symbol for the kind of zone they were taken from and the group they were classified into. For instance, when a watercourse had a bank slope zone which was classified into group 3, an emergent plant species zone which was classified into group 10 and a submerged plant species zone which was classified into group 11, then the gradient sample was defined as a combination of the zone types B-3, E-10 and S-11. The gradient samples were analyzed again with TWINSPAN, resulting in a second order classification in which similar gradient samples are clustered into groups. The results were summarized into a synoptic table in which constancy classes of the zone types for each gradient group are indicated (Table 2). Thus, the gradient groups consist of combinations of zone types that are regularly found to coexist in the same watercourse. In these combinations information can be found on the inter-relationships of the zones by using the information about the zone types from the first classification.

RESULTS AND DISCUSSION

In the primary analyses 1365 zone samples with 450 species were classified into 47 groups. Eleven of these groups were made up of only five samples or less. These latter groups were not considered any further because correlations would lack any significance with so few samples.

In general, the division into groups could be explained to a large extent on the moisture preference of their species (Ellenberg 1979). Groups with samples from dry slopes were at the opposite side in the classification to those groups

TABLE 1. CLASSIFICATION OF ZONE SAMPLES. GROUPS THAT ARE NOT DISCUSSED AND SPECIES WITH NO CONSTANCY HIGHER THAN 40% ARE OMITTED. FIGURES SEPARATED BY A COLON ARE CONSTANCY CLASS AND CHARACTERISTIC PRESENCE. CONSTANCY CLASS OF CONTROL FACTORS AND ZONES INVOLVED ARE PRESENTED AT THE BOTTOM.

Zone Group:	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of zone samples:	41	64	83	16	6	18	29	13	40	6	34	20	24
Mean number of species:	14.6	17.3	18.4	11.3	4.8	3.6	7.1	6.1	8.0	7.2	8.8	8.1	6.3
(grasses)													
Alopecurus geniculatus L.	2:4	+:2	-	-	-	-	-	-	2:5	1:3	-	-	-
Elymus repens (L.) Gould	4:6	2:3	3:5	1:5	-	-	-	-	+:5	-	-	-	+:7
Agrostis stolonifera L.	2:5	5:6	4:6	1:5	-	-	2:3	2:3	2:4	-	2:3	-	1:2
Holcus mollis L.	3:6	1:2	4:6	1:4	-	-	-	-	-	-	-	-	-
Holcus lanatus L.	4:5	5:6	4:5	1:4	-	-	-	-	+:5	-	-	-	-
Lolium perenne L.	4:5	4:5	4:5	3:6	1:4	-	-	-	-	-	-	-	1:4
Poa trivialis L.	4:5	-	+:4	1:4	-	1:2	1:4	-	3:5	-	-	-	-
Alopecurus pratensis L.	+:3	-	+:4	5:6	-	-	-	-	-	-	-	-	-
(ruderals)													
Rumex obtusifolius L.	3:2	1:1	2:2	2:2	-	-	+:1	-	-	-	-	-	-
Ranunculus repens L.	5:3	4:3	5:3	1:4	2:1	-	+:2	-	3:2	-	+:2	-	+:2
Taraxacum officinale s.s. Wiggers	5:3	4:2	4:2	2:4	-	-	-	-	+:2	-	-	-	-
Urtica dioica L.	2:2	3:2	4:3	4:5	-	1:5	+:1	-	+:2	-	-	-	-
Anthriscus sylvestris (L.) Hoffmann	1:1	1:2	1:2	4:4	-	-	-	-	-	-	-	-	+:1
(emergents)													
Phragmites australis (Cavanilles) Steudel	+:1	2:3	1:5	1:4	4:6	1:6	2:4	1:1	+:2	-	1:2	1:3	+:2
Glyceria maxima (Hartman) Holmberg	+:5	2:2	4:3	1:4	5:4	5:6	5:6	5:5	4:5	1:2	2:2	2:3	2:3
Phalaris arundinacea L.	1:4	3:4	4:4	1:2	-	2:4	1:3	3:3	4:4	2:3	1:2	2:2	2:4
Glyceria fluitans (L.) R.Br.	1:3	1:2	1:3	-	2:4	2:3	1:5	1:3	4:6	5:3	2:3	1:3	3:4
(aquatics)													
Callitriche platycarpa Kuetzing	-	+:1	+:2	-	2:3	-	+:3	2:4	3:5	4:7	1:3	1:2	2:3
Elodea nuttallii (Planchon) St.John	-	+:2	-	-	-	-	3:5	1:3	+:2	4:4	5:7	4:5	2:4
Ceratophyllum demersum L.	-	-	-	-	-	-	-	-	-	-	2:3	4:4	1:2
Hydrocharis morsus-ranae L.	-	-	-	-	-	-	2:2	1:3	-	-	2:2	4:3	-
Lemna minor L.	-	-	-	-	-	-	3:4	5:3	1:4	1:4	3:2	5:4	5:5
Spirodela polyrhiza (L.) Schleiden	-	+:1	-	-	-	-	3:4	1:4	+:4	-	3:3	5:4	4:6
(less indicative species)													
Angelica sylvestris L.	+:1	2:2	3:2	-	-	-	-	-	-	-	-	-	-
Epilobium tetragonum L.	-	2:2	3:3	-	-	-	-	-	-	-	-	-	-
Equisetum palustre L.	+:3	-	1:2	2:3	4:4	1:3	+:3	-	2:2	-	+:1	-	-
Festuca ovina L.	-	2:5	2:5	1:5	-	-	-	-	-	-	-	-	-
Festuca rubra L.	2:5	+:2	+:4	2:5	-	1:2	-	-	-	-	-	-	-
Galium aparine L.	-	+:2	1:2	3:4	-	1:6	-	-	-	-	-	-	-
Glechoma hederacea L.	2:3	3:3	3:3	1:3	-	-	-	-	+:3	-	+:4	-	-
Juncus effusus L.	1:3	3:2	2:2	2:3	1:1	1:4	1:3	-	+:3	-	1:3	1:2	-
Lamium purpureum L.	+:2	-	-	3:3	-	-	-	-	-	-	-	-	-
Lemna trisulca L.	-	-	-	-	-	-	1:5	1:5	-	-	1:3	3:3	-
Myosotis palustris (L.) L.	1:3	2:3	2:2	-	-	1:2	2:2	-	3:3	2:2	1:2	1:3	1:2
Potamogeton pusillus L.	-	-	-	-	-	-	1:4	2:3	-	4:4	3:3	1:2	+:3
Ranunculus acris L.	2:2	2:2	1:2	3:3	-	-	-	-	-	-	-	-	-
Ranunculus bulbosus L.	-	-	-	3:3	-	-	+:2	-	-	-	-	-	-
Rumex acetosa L.	3:3	4:3	4:3	1:3	-	-	-	-	+:2	-	-	-	-

Flail cutter	3	-	+	-	-	-	-	1	1	-	-	-	-
Cutter bars with rake	3	+	+	1	-	2	-	-	2	-	+	-	-
Mowing Bucket	1	5	5	5	5	2	5	4	3	4	3	4	3
Cutting boat	-	-	-	1	-	1	-	-	+	1	2	1	2
Control frequency: 1 / yr	+	3	3	-	5	1	1	2	2	4	-	1	-
Control Frequency: 2 / yr	5	3	3	5	-	3	4	3	4	-	3	3	3
Control Frequency: 3 / yr	-	+	+	-	-	-	-	-	-	-	1	-	-
Control Frequency: 4 / yr	-	-	-	-	-	1	+	-	-	-	2	1	1
Control Frequency: 5 / yr	-	-	-	-	-	-	-	-	-	1	-	-	1
sampled in maintance path zone (P)	3	2	1	1	-	-	-	-	-	-	-	-	-
sampled in bank top zone (T)	3	+	+	1	-	-	-	-	-	-	-	-	-
sampled in dry bank slope zone (B)	1	4	5	4	-	-	-	-	-	-	-	-	-
sampled in permanently wet zone (W)	-	+	+	1	-	-	-	-	+	-	-	-	-
sampled in emergent plant species zone (E)	-	-	+	-	5	5	5	4	5	-	1	+	2
sampled in floating-leaved plants zone (F)	-	-	-	-	-	-	+	1	-	4	-	-	2
sampled in submerged plant species zone (S)	-	-	-	-	-	-	+	2	-	2	5	5	2

TABLE 2. CLASSIFICATION OF GRADIENT SAMPLES: CONSTANCY CLASSES OF ZONE SAMPLE TYPES. ONLY ZONE TYPES AND GRADIENT GROUPS THAT ARE RELEVANT TO THE DISCUSSION ARE PRESENTED. FIGURES THAT ARE DISCUSSED IN THE TEXT ARE INDICATED.

Gradient group:	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Number of gradient samples:	13	1	9	3	44	8	3	4	15	3	1	5	70	71	68	8	3	26	35	50	39	5	4
Zone type:																							
B- 2	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-
B- 3	-	-	-	-	-	-	-	-	-	-	-	-	+	5	-	-	-	-	-	-	-	-	3
B-14	-	-	-	-	-	-	-	-	-	-	-	-	+	-	5	-	-	-	-	-	-	-	-
B-15	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	5	5	-	-	-	-	-
B-16	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	1	-	-	5	-	-	4	-
B- 1	-	-	-	-	-	5	-	-	-	-	-	-	-	+	+	5	-	-	-	-	-	-	-
B-17	-	-	-	-	+	-	5	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-
B- 4	-	-	4	-	-	-	-	-	-	-	5	5	-	-	-	-	-	-	-	-	-	-	-
B-18	5	5	2	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E- 5	4	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
E- 6	-	-	5	-	-	-	-	-	-	-	-	1	-	1	+	-	-	+	+	+	-	1	-
E- 9	-	-	-	5	4	3	4	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
E-19	-	-	-	-	-	-	-	4	-	-	-	-	-	+	+	-	-	-	+	1	+	-	-
E- 8	-	-	-	-	-	-	-	-	1	-	-	-	+	1	-	-	-	1	1	-	-	-	-
E- 7	-	5	-	-	-	-	-	-	-	5	-	2	1	2	1	-	-	-	1	+	-	-	-
E-20	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	+	1	-	-
E-21	-	-	-	-	-	1	-	-	-	-	5	-	+	+	+	-	-	-	1	1	-	-	-
S-10	-	-	2	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
S-22	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
S-23	-	-	-	-	+	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
S-11	-	-	-	-	+	-	5	-	-	-	-	2	2	1	1	2	-	+	1	-	-	-	-
S-12	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1	-	-	+	-	-	-	-	-
S-24	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	4	-
S-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
S-26	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1	-	-	-	5
F-13	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	5	-	1	-	+	-	-
F-27	-	-	-	2	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
F-28	-	-	-	-	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-

Zone types:
B = Bank slope zone type
E = Emergent plant species zone type
S = Submerged plant species zone type
F = Floating-leaved species zone type
Number: zone sample group in Table 1.

comprising only submerged species. At lower levels the division of several groups could be explained for a large part on the trophic state of the species (Ellenberg 1979). Other low level divisions could be explained mainly on vegetation structure: dominant large species versus low growing species, or submerged species versus floating-leaved or emergent species. In some cases two related groups differed merely for the one having clearly more annual species.

Four types of machines for control of the vegetation were used more often than other machines. The impact of these machines on the vegetation differs. Cutting boats only cut the plants growing in the water with their V-shaped knifes pulled along the bottom. Flail cutters used for maintenance paths and slope zones chop the plant material into very small pieces which decay very rapidly. Most of the machines which operate from the maintenance path and use cutter bars, rake the plants to the bank top or onto the maintenance path. They can reach into the water as far as the emergent zone. Mowing buckets cut the plants in the water and on the slopes and dump the cut material on the maintenance path. Machines that remove the cut plants to another zone cause a shift in trophic state from one zone to the other. Control frequency does not depend on the machinery, but in general cutting boats are used more frequently than the other machines and mowing buckets are not used more than twice a year.

Table 1 shows some of the groups in the classification of zone samples. The choice for these 13 groups out of 47 is based on the possibility to interpret the differences as effects of management techniques, both as zone groups and as part of gradient groups in the second order classification. Species that had no constancy higher than 40% in any of the presented zone groups are omitted. In the second part of the table the constancy classes of the control techniques, of the control frequency, and of the zones in which the samples were taken are presented.

Groups in which *Elodea nuttallii* and *Lemna minor* have a high constancy also have a high constancy for high frequency of control measures: groups 11 and 12 for instance. Groups with ruderal species such as *Urtica diocia*, *Anthriscus silvestris* and *Rumex obtusifolius* had control techniques that left the cut plants in the zone, or dumped plants from other zones into them. Group 1 is such a group. Approximately half of the 41 samples in this group are from maintenance path zones, the other half from bank top zones. In half of the samples a flail cutter was used and in the other half a cutterbar with rakes was used which transported the cut plants into the bank top zone or onto the maintenance path. Some of the species with constancy class 3 or higher in this group such as *Taraxacum officinale*, *Rumex obtusifolius*, *Ranunculus repens*, *Lolium perenne* and *Elymus repens* are typically known from eutrophic habitats.

There were five groups in which *Glyceria maxima* had a high constancy: groups 5, 6, 7, 8 and 9. Group 6 contains the samples in which *G. maxima* was most dominant; in the other groups other species were also important. Group 5 differs from the others having both a low control frequency and *Phragmites australis* as the next most important species.

In the second order analyses gradient samples were classified into 51 groups. Table 2 shows the groups that are discussed in this paper and other groups that show considerable constancy with the presented zone types.

Gradient groups A to K all have a high constancy for some emergent plant species zone type. They also have high constancy figures for at least one other zone type. Gradient groups D, E, F and G do not differ in emergent plant species zone type, but they do in bank slope zone type. On the other hand, gradient groups G, H, I and J do not differ in bank slope zone type, but they do in emergent plant species zone type. The only explanation for these differences that could be found was that the vegetation on these bank slope zones is more or less independent from the emergent plants species zones.

In gradient group C, a combination of zone type E-6 with zone types B-4 and either S-10 or F-13 was found. Zone type E-6 is the one with a strong dominance of *Glyceria maxima*. Zone type B-4 had both high constancy and characteristic presence of ruderal species such as *Urtica dioica*, *Anthriscus sylvestris*, *Galium aparine* and *Alopecurus pratensis*. Zone type F-13 has samples with a dense cover of *Lemna minor* and *Spirodela polyrhiza*, and can be considered as one of the most ruderal vegetation types in ditches. Zone type S-10 has amphibious species such as *Callitriche platycarpa* and *Glyceria fluitans*. Control frequency is lower in zone type S-10 than in zone type F-13. The conclusion might be that in similar eutrophic watercourses with dense stands of *Glyceria maxima*, there can be either a vegetation dominated by lemnids (duckweeds) or a vegetation with submerged or amphibious plants. Control frequency could explain the difference between the two.

There are indications that there is a relationship between those submerged plant species zone types with fast growing plants such as *Elodea nuttallii*, *Ceratophyllum demersum*, accompanied by floating species such as *Lemna minor* and *Spirodella polyrhiza*, and certain types of other zones. The submerged plant species zone type S-11 in which *E. nuttallii* is the dominant species combines best with the *Glyceria maxima* zone type E-9, the most species rich one (gradient group G). However, in this group there are only three gradient samples. The zone type in which only lemnids (duckweeds) dominate, zone type S-12, combined only poorly with other groups. Types B-2, B-3 and B-14 combine either with type S-12 or with type S-11 (gradient groups M, N and O). These bank slope zone types are dominated by short grasses that are cut once or twice a year, and in more than 80% of the gradient samples. There is no emergent plant species zone in these gradients because the plants are cut too often. From these data it appears that fast growing aquatic plants gain some advantage from the absence of emergent vegetation. This has implications for management practices. Emergent plant species zones can be useful as a natural tool for reducing the growth of the more troublesome submerged plants and duckweeds by competition.

Splitting up the vegetation gradient into zones proves to be a method that makes it possible to analyze interactions between these zones and the management techniques, although most of the relations that are found this way are indicative, and the methods used cannot be statistically tested. The role of the emergent plant species zone is one example of how these data can be interpreted to explain the effects of mechanical control on watercourse vegetation. More detailed information will be produced when more watercourses have been sampled and compared.

ACKNOWLEDGMENTS

I wish to thank Dr. K. V. Sýkora for his inspiration in developing the methods described.

LITERATURE CITED

Barkman, J. J., J. Doing and S. Segal. 1964. Kritische Bemerkungen und Vorschläge zur quantitativen Vegetationsanalyse. Acta Botanica Neerlandica 13:394-419.

Ellenberg, E. 1979. Zeigerwerte des Gefäszpflanzen Mitteleuropas. Scripta Geobotanica 9, Göttingen, 121 pp.

Hill, M. O. 1979. TWINSPAN. A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics. Cornell University, Ithaca, NY, 90 pp.

Westhoff, V. and E. Van der Maarel. 1973. The Braun-Blanquet approach. *In*: R. H. Whittaker (ed.). Ordination and classification of communities. Handbook of Vegetation Science 5:617-726.